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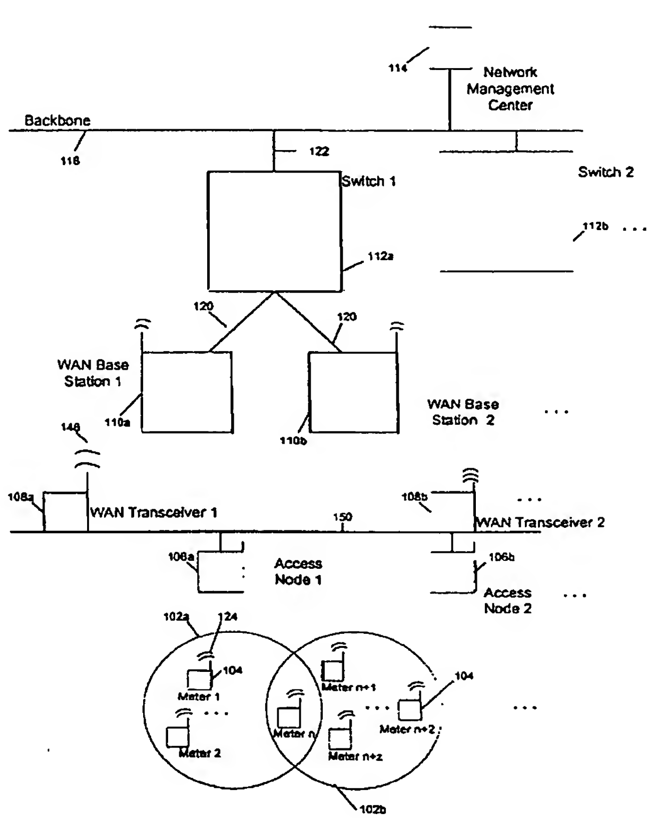
(54) Title: SYSTEM AND METHOD FOR HIERARCHICAL NETWORK FOR USE IN REMOTE DATA SENSING



(57) Abstract: A system and method for remote sensing of utilities and other data incorporates a multiple level network hierarchy. Individual sensor units, such as electrical meters, may be equipped with a relativity small, low-cost wireless link, such as a Bluetooth link, to create self-configuring piconets in a neighborhood or other reporting cell. Metering or other data collected by the sensors may be relayed through an access node which communicates the LAN-based information to a WAN resource, such as a Mobitex transceiver. That transceiver may operate an extended geographic region of 30 kilometers or more, collecting information from reporting cells or groups of reporting cells for transmission to a base station. One or more of those base stations communicate via a switch to a network management center, which receives, conditions, restores and processes the data, for instance, for billing or other purposes. Because the reporting devices may be low cost, low power units, a large quantity of utility or other resources may be monitored and a large number of reporting cells may be economically maintained.

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System And Method For Hierarchical Network For Use in Remote Data Sensing

Field of the Invention

The invention relates to the field of communications, and more particularly to the remote sensing of utility or other data via a hierarchical data network.

Background of the Invention

In the field of remote data sensing, a variety of industrial telemetry and other reporting systems have been developed and deployed. For instance, in the railroad, trucking or other transportation markets, remote inventory, rolling stock or other asset and schedule tracking has sometimes been accomplished by means of wireless data links. One wireless transport technology used for industrial telemetry applications is the Mobitex™ wireless link developed by Ericsson of Sweden. The Mobitex™ system is a commercial-quality, duplex wireless data transport protocol operating in either the 400 MHz or 900 MHz frequency bands.

Mobitex™ and other wireless wide area network (WAN) systems offer good data reliability and good geographic coverage, in the case of Mobitex™ extending up to 30 kilometers or more. However, while the service footprint is wide, the data rates of Mobitex™ links are relatively modest, typically 8.2 to 19.2 kilobits per second (kbs). Moreover, the wireless transceiver, base station and other associated equipment

deployed in Mobitex™ installations may be relatively expensive to consider for high volume installations, at least for the data rates offered.

Thus, the use of WAN wireless technology to establish high-volume or consumer utility metering links, such as electric, gas or water meters, has been limited. Such installations have been attempted, for instance, in the public electric grid in Turkey. However, the low data rates and high cost of installation has made wireless WAN technology a less than fully attractive solution for utility providers on a consumer scale.

Conversely, short-range local area network (LAN) technology exists which can tie together a variety of data producing devices within a few meters' distance on a low-cost basis. However, wired or wireless LANs do not offer the physical range or network scaleability to permit electric meters, water meters, gas meters or other utility devices to be assembled into neighborhood, town or other reporting grids. Better, more flexible network technology for telemetry and other service purposes is desirable.

Summary of the Invention

The invention overcoming these and other problems in the art relates to a system and method for a hierarchical network with remote sensing applications, in which electric power or other utility or other sensors report data via a multiple level network for billing, maintenance or other purposes. More particularly, in the invention a relatively short-range LAN technology may be embedded within the housing of utility sensors such as electric meters. In one embodiment, the LAN

technology may be or incorporate the commercially known Bluetooth wireless protocol to establish small self-configuring networks (piconets), which are then grouped into larger collections of reporting cells. This collection of reporting cells may communicate wirelessly with a base station of a high-level wireless WAN, for uplink to a network control center for billing, monitoring and other purposes. In one embodiment of the invention, the wireless WAN technology may incorporate the Mobitex™ protocol for data uptake from the underling Bluetooth LAN.

Because data is mediated by both a low-cost, short-range LAN technology for collection purposes and a broader-scale WAN technology for supervisory purposes, the hierarchical network according to the invention may cover a significant geographic area without incurring as much network support cost as, for instance, a dedicated WAN system. Installation, maintenance and upgradeability and may be enhanced, and utility billing, repairs and operations may be made more efficient by practicing the invention.

Brief Description of the Drawings

The invention will be described with respect to the accompanying drawings, in which like elements are referenced with like numerals.

Figure 1 illustrates an overall communications network architecture according to an embodiment of the invention.

Figure 2 illustrates a flow chart of telemetry processing according to the invention.

Figure 3 illustrates an air link between a sensing device and a wireless LAN interface according to an embodiment of the invention.

Figure 4 illustrates a hierarchical grouping of WAN elements to achieve broad geographic coverage according to the invention.

Figure 5 illustrates aspects of data transport according to an embodiment of the invention.

Figure 6 illustrates an air link between a sensing device and a wireless LAN interface according to another embodiment of the invention.

Detailed Description of the Preferred Embodiments

As illustrated in Figure 1, in general in the network architecture of the in invention, a group of individual sensing devices 104 may sense electric, gas, water or other utility conditions for reporting to a central station for maintenance, diagnosis, billing and other service or operational purposes. Although generally illustrated as electric power meters, it will be understood that other sensors are possible. As illustrated in Figure 1, in an embodiment of the invention, the sensing devices 104 may be grouped into a set of reporting cells 102a, 102b ... (ellipses denoting an arbitrary number for this and other elements) which detect the reporting devices and collect data streams from a set of sensing devices 104 for conditioning and communication.

As also illustrated in Figure 1, each of the sensing devices 104 may include a wireless link 124 for establishing links within a reporting cell and with upstream data

resources. In a preferred embodiment of the invention, the wireless link 124 may be or incorporate the Bluetooth wireless protocol. As will be understood by persons skilled in the art, the wireless link 124 according to the Bluetooth implementation may include a 2.4 GHz wireless transmission link, the wireless link 124 operating on a frequency hopping, time division duplex (TDD) basis, as for instance described in Standard 802.15 of the Institute of Electrical and Electronics Engineers (IEEE), incorporated by reference.

In general, the Bluetooth wireless interface may have a range of 1 to 10 meters in the 2.4 GHz (ISM, Industrial Scientific and Medical) unlicensed radio frequency band. In an implementation of the invention of this type, the reporting cells 102a, 102b ... may correspond to Bluetooth piconets, which in one embodiment may represent up to 8 Bluetooth nodes communicating in a self-configuring master/slave network ring. Thus, the reporting cell 102a in an embodiment of the invention may include a set of 8 electric power or other meters each containing a Bluetooth transceiver, each sensing and communicating with the remainder of the sensing devices 104 within the reporting cell 102a, 102b....

In an electrical metering implementation, the sensing device 104 may detect and report via the wireless interface 124 data such as instantaneous and average power consumption (in watts or kilowatt hours), line voltage, line fault and other data. As also illustrated in Figure 1, one or more of the sensing devices 104 may overlap and be incorporated in more than one of the reporting cells 102a, 102b ... according to desired network configuration, an arrangement referred to as a scatternet. The

reporting cells 102a, 102b ... thus represent small-scale LANs sharing radio sink, sensor and other data, in daisy-chain or other fashion.

At a next level of transmission hierarchy, one or more sensing devices 104 within each of the reporting cells 102a, 102b ... may communicate with one or more of an associated set of access nodes 106a, 106b .... Each of the access nodes 106a, 106b ... may be equipped with Bluetooth or other wireless interfaces compatible with wireless interface 124, to receive electrical or other telemetry data from each associated reporting cell.

As illustrated in more detail in Figure 3, each of the access nodes 106a, 106b ... may include a Bluetooth interface 128 along with a radiating element 130 to receive and transmit signals to the reporting cells. In an architecture of the invention, each of the access nodes 106a, 106b ... may act as a bridge to a next-level wireless WAN for communication of the remote sensing data to a higher network level.

More particularly, as illustrated for instance in Figure 1, each of the access nodes 106a, 106b ... may communicate with a communications link 150, such as a wired LAN to which a group of WAN transceiver nodes 108a, 108b ... may be connected. Each of the WAN transceiver nodes 108a, 108b ... may include transceiving equipment to communicate over a wireless WAN link 148. In a preferred embodiment, wireless WAN link 148 may be, incorporate or interface to the Mobitex™ wireless protocol, operating for instance at frequencies of 400 MHz or 900 MHz and at data rates of 8.2 - 19.2 kbs, although other data rates and air interfaces are possible.

Each of the WAN transceiver nodes 108a, 108b ... may communicate via a wireless WAN link 148 to a corresponding one or more of a set of base stations 110a, 110b ... . The range over which wireless link 148 may connect individual ones of WAN transceiver nodes 108a, 108b ... and corresponding ones or more of base stations 110a, 110b ... may vary but may generally be in the range of up to 30 kilometers or more, depending on transmission power, terrain and other factors. Each of the WAN transceiver nodes 108a, 108b ... need only communicate with at least one base station 110a, 110b... . However, in different implementations one or more of the WAN transceiver nodes 108a, 108b ... may communicate with more than one of the base stations 110a, 110b... .

In one embodiment, each of the base stations 110a, 110b... may be, incorporate or interface to, for instance, a BRU3 Mobitex™ base station manufactured by Ericsson. As noted, when implemented as a Mobitex™ protocol, the wireless link 148 may operate, for instance, on 400 MHz or 900 MHz frequency bands, using the x.25, HDLC, MASC or other networking protocols. Each of the base stations 110a, 110b... may therefore service a large number of underlying sensing devices 104 mediated by the reporting cells 102a, 102b... communicating with associated access nodes 106a, 106b... . Those nodes may link with WAN transceiver nodes 108a, 108b... in turn communicating via the wireless WAN link 148 to associated base stations 110a, 110b... . to form a multiple level wireless network for sensing and other purposes. The hierarchical nature of the communications network according to the invention permits flexibility in placement, configuration and re-configuration,

coverage redundancy and other operating perimeters for electric utility and other telemetry applications.

The base stations 110a, 110b... may in turn communicate with one or more associated switches 112a, 112b.... The switches 112a, 112b... may collect and distribute data streams from originating from the various reporting cells 102a, 102b... to a network management center 114 via communications link 122 connected to a backbone link .116. The composite architecture of the invention may therefore flexibly service an extended geographic area, for instance as illustrated in Figure 4, since the sensor, LAN, WAN and other components are extensible over geographic boundaries which may be on a neighborhood, town, city or other scale.

However, according to the invention the terminal sensing is not deployed in a WAN mesh, since the WAN layer of the network hierarchy is reserved for uplink to and downlink from a centralized network control center. While the wireless interface 124 connecting various LAN components according some embodiments of the invention may have a higher data rate capacity than the wireless link 148 connecting the WAN components, in general the base station 110a, 110b... may need to communicate via wireless link 148 to WAN transceiver nodes 108a, 108b... on a less frequent basis than the sensing devices 104 in the reporting cells 102a, 102b.... .

That is, for example, as for instance illustrated in the arrangement of Figure 3, the sensing device 104 includes an electrical metering interface 134 sensing kilowatt hours, amps, voltage, or other data, while the Bluetooth link manager 136 of the sensing device 104 may need to communicate with other sensors within a reporting

cell to maintain the wireless piconet, the base station 110a, 110b... may need to collect electrical usage data only on a weekly, monthly or other less frequent basis. Thus, bandwidth resources may be conserved on the WAN uplink or downlink according to the invention, increasing bandwidth efficiency.

As also illustrated in Figure 3, each of the access nodes 106a, 106b... may include a Mobitex™ interface 126 to interface with the Bluetooth interface 128 to receive and convert data into packets appropriate for the Mobitex™ WAN transmission protocol. As more particularly illustrated, for instance, in Figure 5, in the transmission uplink and downlink the sensing device 104 may communicate in the Bluetooth format using a frequency hop/TDD scheme in which frequencies are shifted (F_K, F_K +1, F_K +2...) every 625 micro-seconds, for a data hop rate of 1600 hops per second.

When wireless link 124 is implemented in that Bluetooth scheme, the transmission packets may include an access code 140 consisting of 72 bits, a header packet 142 consisting of 54 bits, and a data payload 144 of up to at least 2,475 bits. The data payload 144 illustratively represents remote electric meter data, but other data may be sensed. The resulting Bluetooth data stream may be received and interpreted by an access node 106a, 106b...from which the meter data 144 may be extracted for communication to WAN transceiver node 108a, 108b... . In the WAN transceiver node 108a, 108b..., the radio link may transmit re-packeted metered data 146 as the data payload to the base station 110a, 110b.... Transmission between WAN transceiver node 108a, 108b...and base station 110a, 110b... need not be

synchronous with communications between one or more sensing device 104 and access node 106a, 106b.... .

Overall processing according to an embodiment of the invention is illustrated in the flowchart of Figure 2. In step 202, processing begins. In step 204 one or more of the sensing devices 104 may be activated. In step 206, a wireless LAN (e.g. Bluetooth) link may be established between one or more sensing device 104 and one or more of the access nodes 106a, 106b... . In step 208, a communications link may be established between one or more of the access nodes 106a, 106b... and one or more of the WAN transceiver nodes 108a, 108b... . In step 210, utility metering or other data may communicated from a sensing device 104 located in the reporting cell 102a, 102b... to the transceiver in one or more of the WAN transceiver nodes 108a, 108b.... In step 212, the data received in the corresponding one or more of the WAN transceiver nodes 108a, 108b... may be buffered or conditioned as necessary.

In step 214, a link may be established between one of the WAN transceiver nodes 108a, 108b... and one or more of the base stations 110a, 110b.... In step 216, the remotely sensed data may be communicated from one or more of the base stations 110a, 110b... to a corresponding one or more of switches 112a, 112b.... In step 218, data may be communicated from one or more switch 112a, 112b...to the network back bone 116. In step 220, the data may be monitored, stored and distributed at the network management center 114 for billing, maintenance and other purposes. In step 222, the WAN (Mobitex), LAN (Bluetooth) and other network elements may be configured, reprogrammed, maintained and managed as necessary. In step 224,

billing information may be communicated to individual consumers as necessary. In step 226, processing ends.

The foregoing description of the hierarchical sensing network according to the invention is illustrative, and variations in configuration and implementation will occur to persons skilled in the art. For instance, while the LAN wireless link 124 has been illustratively described in terms of being implemented using the Bluetooth protocol, other protocols or simultaneous groups of protocols may be employed.

As shown in Figure 6, in another embodiment of the invention one or more sensing device 104a, 104b ... may include more than one protocol module. In Figure 6, illustratively a General Packet Radio Service (GPRS) module 152 may be installed in addition to the Bluetooth link manager 136. The GPRS module 152 may be configured to operate in one or more packet-switched modes, including for example X.25 or Internet Protocol modes, operating on 400MHz, 900 MHz, 1800MHz, 1900Mhz or other frequency bands associated with that standard. In one implementation, the GPRS module 152 and the Bluetooth link manager 136 may be incorporated or embodied in a single integrated circuit or chip, such as those made or marketed by Research In Motion Limited. The Bluetooth interface 128 and GPRS interface 154 may be similarly integrated into a single integrated circuit or chip. In this embodiment, one or more access node 104a, 104b ... may include a GPRS interface 154, to exchange information on one or the other or both the Bluetooth and GPRS radio frequency links. For example, this embodiment the relatively higher capacity of 128Kbits/sec or more of the GPRS protocol linking one or more sensing device 104a, 104b ... to one or more access node 106a, 106b ... may be used for

alternative purposes, such as on-demand data reads, higher-throughput metering needs or for general network backup, in the event of interruption of the Bluetooth connection or other failure conditions.

Similarly, while wireless link 148 on the WAN side has been illustratively described in terms of a Mobitex™ link, other wireless WAN technology, for instance, general packet radio service (GPRS), HyperLAN II, IEEE 802.11 or other wireless packet, cellular or other technology, including those operating on other frequency bands such as the 5 GHz band, may also be employed.

Similarly, while the invention has been described with respect to single protocols operating at the LAN and WAN levels, multiple protocols could be integrated in each. Further, while sensing devices 104 have been described has of a single type, for instance electrical metering, heterogeneous sensing devices 104 sensing different types of utilities or quantities may also be integrated within a system according to the invention.

Yet further, while the invention has been generally described in the context of the remote sensing of utility or other data transmitted on an uplink to a network center, in general each of the wireless links and other communications resources may be duplex and data may flow in both directions, including for instance to reprogram the sensing devices for repair, update or other purposes. And yet further, while the invention has generally been described in terms of nested LAN and WAN networks, each of which operates wirelessly, each of the LAN and WAN levels or components

thereof may consist of or include wired network elements. The scope of the invention is accordingly intended to be limited only by the following claims.

What is claimed is:

1. A system for sensing data, comprising:

a first interface to a local area network, the local area network communicating with at least one sensing device generating sensing data;

a second interface to a wide area network, the wide area network communicating with at least one network management resource; and

at least one access node, communicating with the first interface and the second interface, the access node mediating the flow of the sensing data between the first interface and the second interface.

2. The system of claim 1, wherein the first interface comprises a wireless local area network interface.

3. The system of claim 2, wherein the wireless local network interface comprises a Bluetooth interface.

4. The system of claim 3, wherein the Bluetooth interface comprises a wireless connection to at least one piconet.

5. The system of claim 4, wherein the at least one sensing device is associated with the at least one piconet.

6. The system of claim 5, wherein the at least one piconet comprises a plurality of piconets, the at least one sensing device comprises a plurality of sensing devices, and each of the plurality of sensing devices is associated with at least one of the plurality of piconets.

7. The system of claim 6, wherein at least one of the plurality of sensing devices is associated with at least two of the plurality of piconets.

8. The system of claim 1, wherein the at least one sensing device comprises at least one of an electric sensing device, a water sensing device, and a gas sensing device.

9. The system of claim 1, wherein the second interface comprises a wireless wide area network.

10. The system of claim 9, wherein the wireless wide area network comprises at least one of a Mobitex interface, a HyperLAN II interface, and a General Packet Radio Service interface.

11. The system of claim 9, wherein the wireless wide area network comprises an interface to at least one base station.

12. The system of claim 11, wherein the wireless wide area network comprises an interface to at least one switch.

13. The system of claim 12, wherein the at least one network management resources comprises at least one central control facility.

14. The system of claim 13, wherein the at least one central control facility comprises a billing facility to generate billing information based on the sensing data.

15. The system of claim 13, wherein the at least one base station comprises a plurality of base stations, the at least one switch comprises a plurality of switches, the at least one sensing device comprises a plurality of sensing devices, and each of the plurality of sensing devices is associated with at least one of the plurality of base stations.

16. The system of claim 15, wherein the each of the plurality of switches routes the sensing data from at least one of the plurality of sensing devices to the at least one central control facility.

17. A method of sensing data, comprising:

a) communicating via a local area network with at least one sensing device generating sensing data;

b) communicating via a wide area network with at least one network management resource; and

c) mediating the flow of the sensing data between the local area network and the wide area network at least one access node.

18. The method of claim 17, wherein the local area network comprises a wireless local area network.

19. The method of claim 18, wherein the wireless local network comprises a Bluetooth network.

20. The method of claim 19, wherein the Bluetooth network comprises a wireless connection to at least one piconet.

21. The method of claim 20, further comprising a step of d) associating the at least one sensing device the at least one piconet.

22. The method of claim 21, wherein the at least one piconet comprises a plurality of piconets, the at least one sensing device comprises a plurality of sensing devices, further comprising a step of e) associating each of the plurality of sensing devices with at least one of the plurality of piconets.

23. The method of claim 22, further comprising a step of f) associating at least one of the plurality of sensing devices with at least two of the plurality of piconets.

24. The method of claim 17, wherein the at least one sensing device comprises at least one of an electric sensing device, a water sensing device, and a gas sensing device.

25. The method of claim 17, wherein the wide area network comprises a wireless wide area network.

26. The method of claim 25, wherein the wireless wide area network comprises at least one of a Mobitex interface, a HyperLAN II interface, and a General Packet Radio Service interface.

27. The method of claim 26, wherein the wireless wide area network comprises at least one base station.

28. The method of claim 27, wherein the wireless wide area network comprises at least one switch.

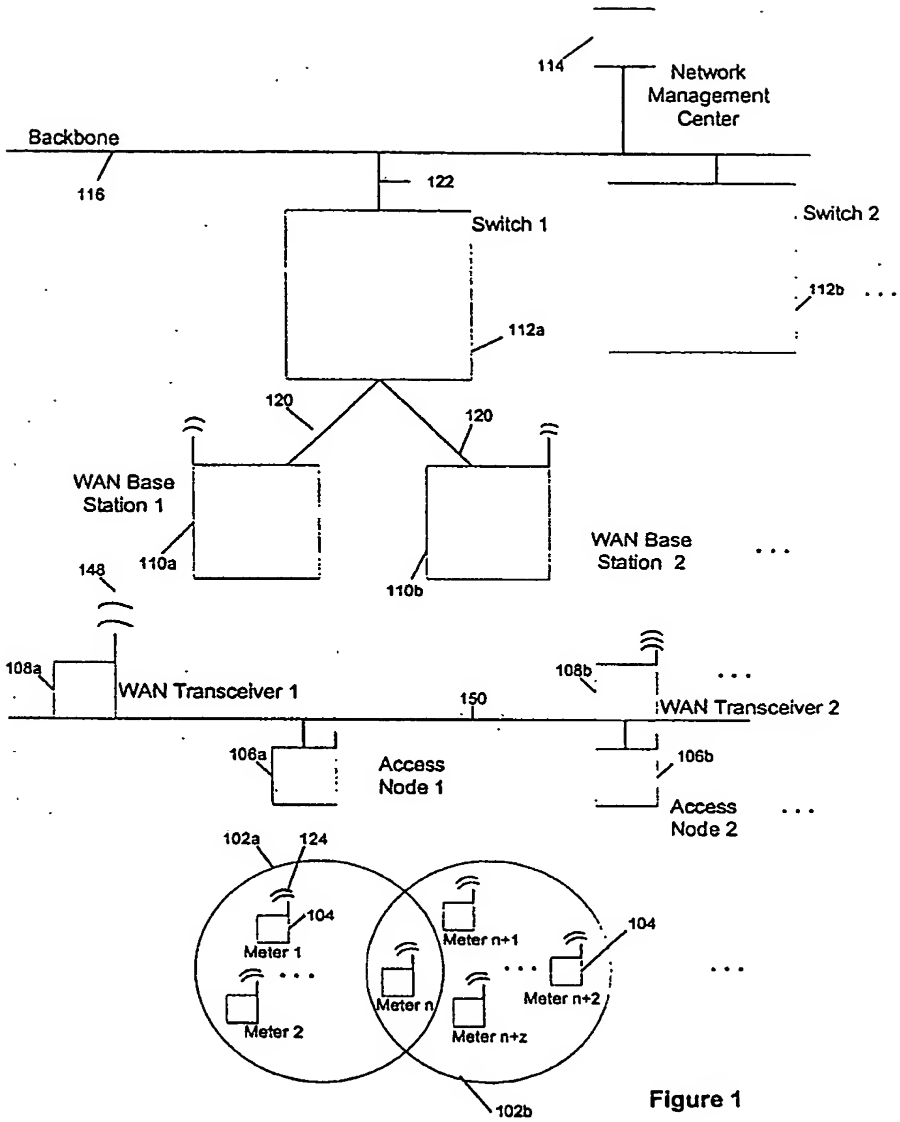
29. The method of claim 28, wherein the at least one network management facility comprises at least one central control facility.

30. The method of claim 29, wherein the at least one central control facility comprises a billing facility, further comprising a step of g) generating billing information based on the sensing data.

31. The method of claim 30, wherein the at least one base station comprises a plurality of base stations, the at least one switch comprises a plurality of switches, the at least one sensing device comprises a plurality of sensing devices,

further comprising a step of h) associating each of the plurality of sensing devices with at least one of the plurality of base stations.

32. The method of claim 31, further comprising a step of i) routing the sensing data from at least one of the plurality of sensing devices via at least one of the plurality of switches to the at least one central control facility.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Network
Management
Center
Backbone
116
122
Switch 1
Switch 2
112b
112a
120
120
WAN Base
Station 1
110a
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110b
148
108a
WAN Transceiver 1
150
108b
WAN Transceiver 2
106a
Access
Node 1
106b
Access
Node 2
102a
124
104
Meter 1
Meter 2
Meter n
Meter n+1
Meter n+2
Meter n+z
104
102b

Figure 1

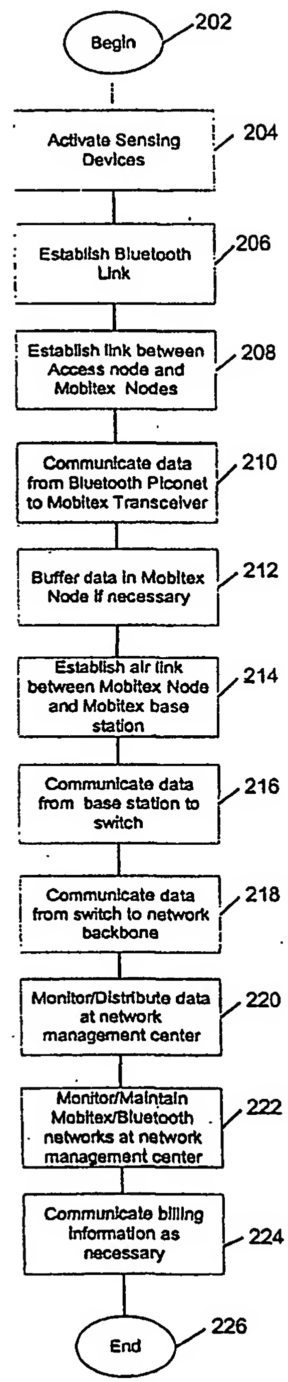
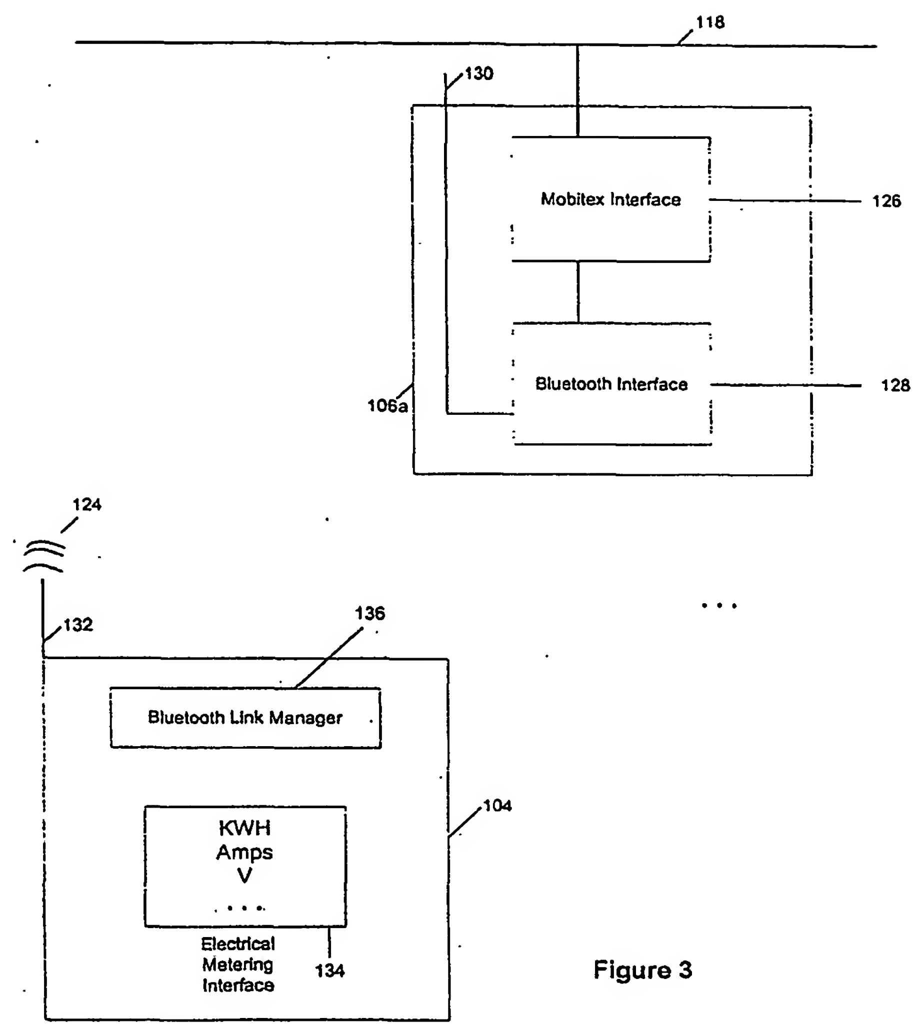

Begin
202
Activate Sensing Devices
204
Establish Bluetooth Link
206
Establish link between Access node and Mobitex Nodes
208
Communicate data from Bluetooth Piconet to Mobitex Transceiver
210
Buffer data in Mobitex Node if necessary
212
Establish air link between Mobitex Node and Mobitex base station
214
Communicate data from base station to switch
216
Communicate data from switch to network backbone
218
Monitor/Distribute data at network management center
220
Monitor/Maintain Mobitex/Bluetooth networks at network management center
222
Communicate billing information as necessary
224
End
226

Figure 2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Mobitex Interface
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Bluetooth Interface
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124
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Amps
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Interface
134

Figure 3

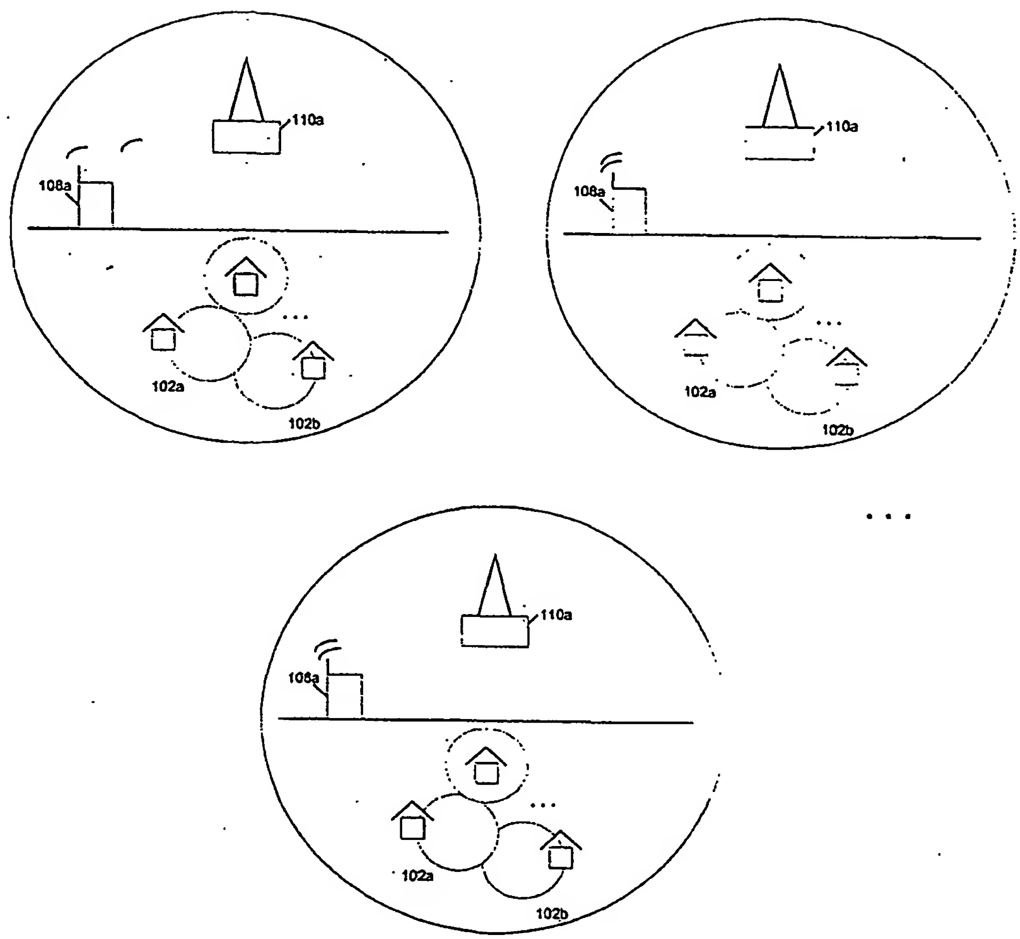
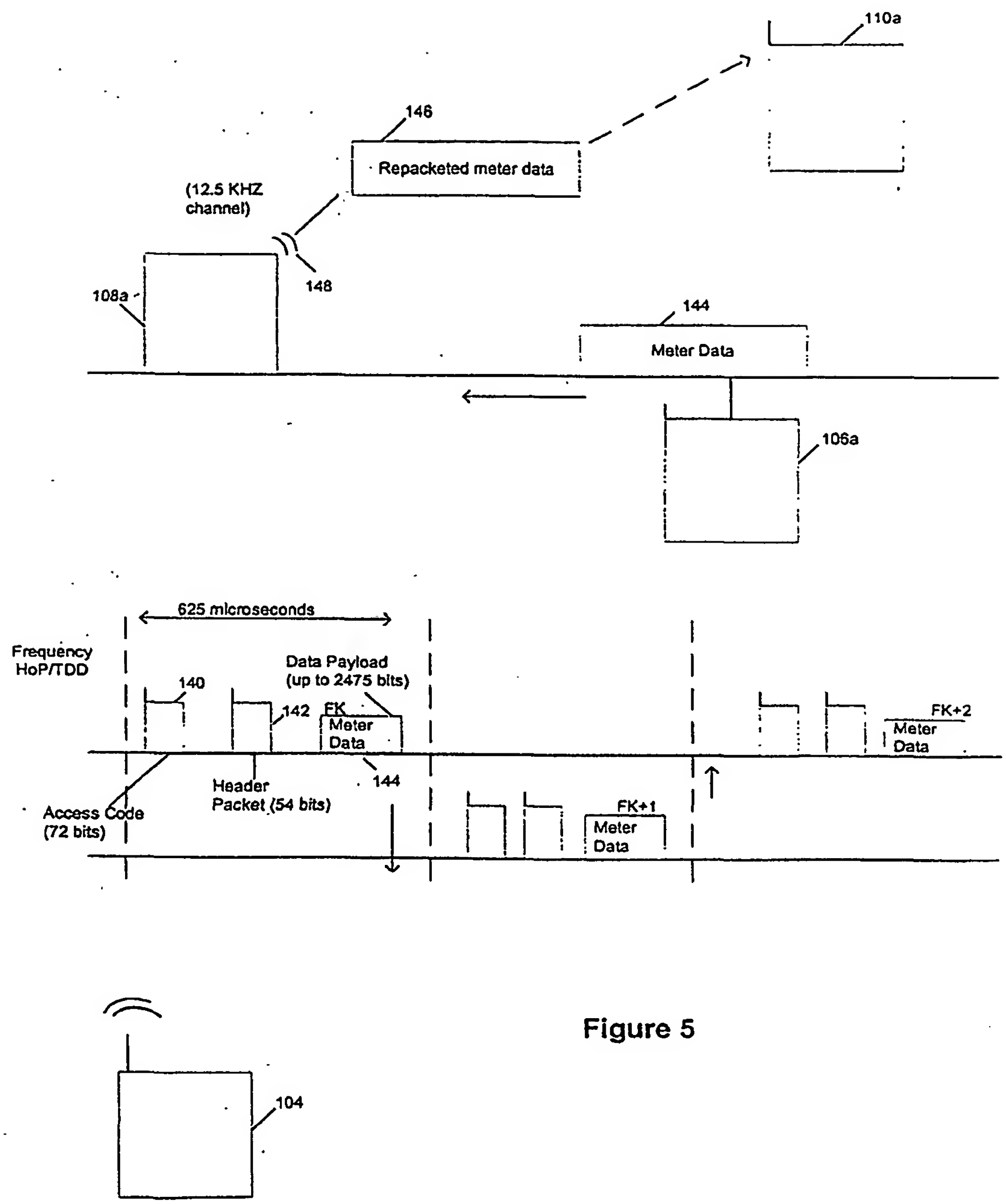


Figure 4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108a
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Frequency HoP/TDD
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140
142
FK
Meter Data
144
Header Packet (54 bits)
Access Code (72 bits)
FK+1
Meter Data
FK+2
Meter Data
104

Figure 5

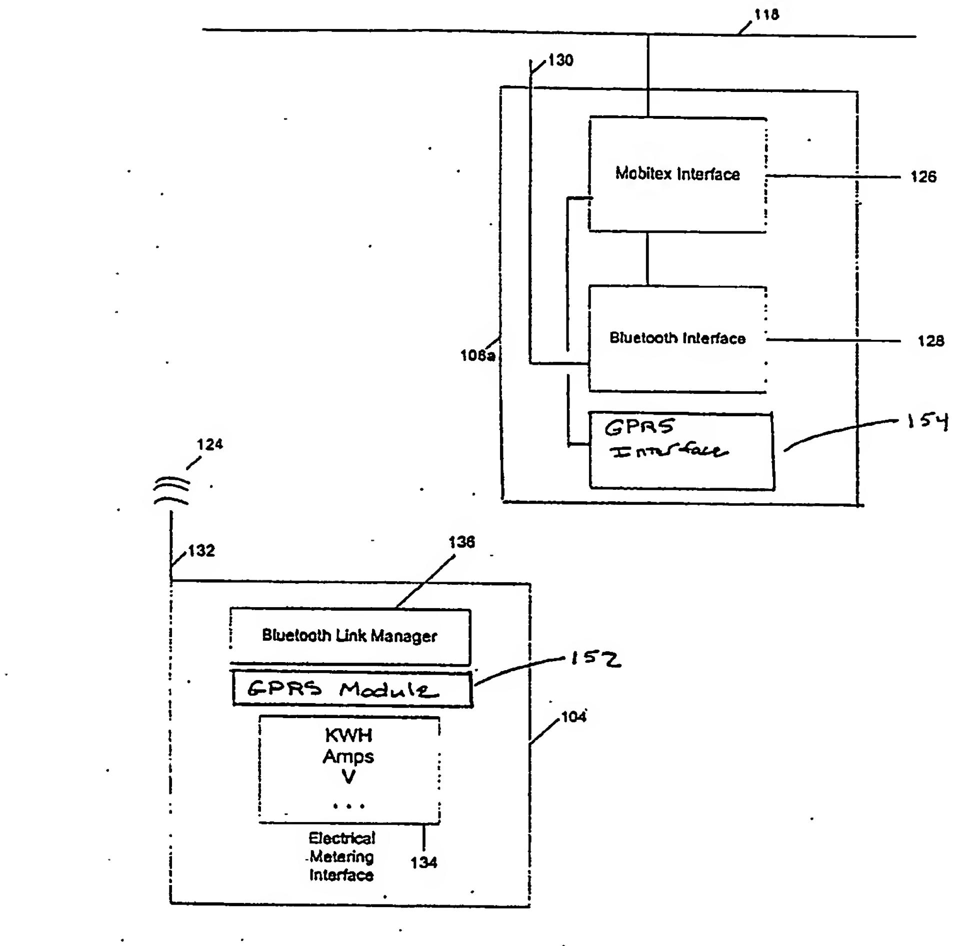
118
130
Mobitex Interface
126
Bluetooth Interface
128
108a
GPRS Interface
154
124
132
136
Bluetooth Link Manager
152
GPRS Module
104
KWH
Amps
V
...
Electrical
Metering
Interface
134

Figure 6